APPENDIX A ENERGY COST BUDGET METHOD

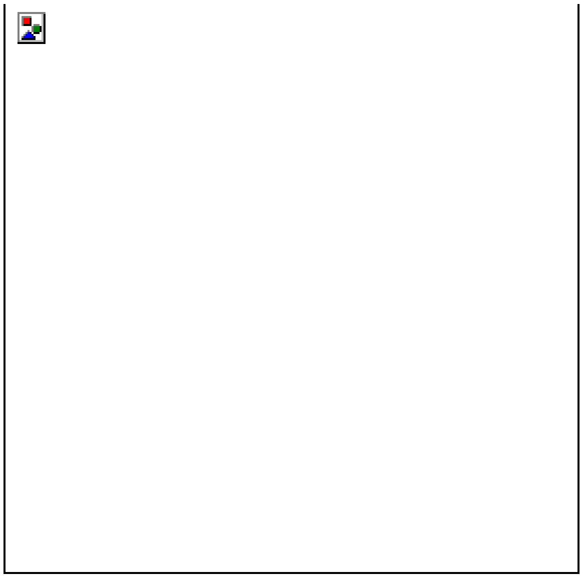
General Information

Section 102 of the 90.1 Code offers maximum design flexibility by permitting the use of the energy cost budget (ECB) method to evaluate the performance of a building in its entirety. With the ECB method, a building design is evaluated based on the *cost* of various types of energy used, rather than the *units* (Btu, kWh) of energy used. Basically, you demonstrate that the annual energy cost of your design is less than that for a reference building that meets either the prescriptive or the system performance criteria. This lets you calculate energy use of different fuel sources at different times. One of the advantages of the ECB method is that it gives you credit for innovative energy-efficient designs not accounted for in the prescriptive or system performance paths, such as passive solar heating and daylighting. This is because the prescriptive and system performance methods set minimum performance levels for building components or systems, while the ECB method takes into account how various building components interact.

WHEN TO USE THE ENERGY COST BUDGET METHOD

The ECB method may be used when the proposed building cannot meet either the prescriptive or system performance criteria; or when you need more flexibility for a more innovative design. The ECB method can help you achieve the most energy-efficient and cost-effective design solution.

Another important advantage of the ECB method is that it lets you evaluate not only compliance, but the margin by which a project complies. This margin is used by some utilities as a basis for energy efficiency rebates. The only disadvantage of the



ECB method is its complexity. You must be familiar with building energy simulation programs, some of which are difficult to master. This section provides guidelines for modeling a building and for determining compliance, but it does not include instructions for using the building energy simulation programs.

BASIC REQUIREMENTS

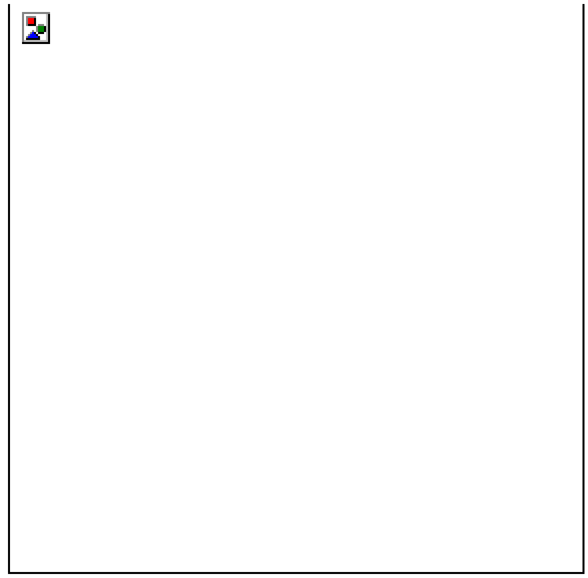
Although the energy cost budget method permits trade-offs in energy use between different building systems, the proposed design must still comply with the basic requirements. Basic requirements are separately specified in ASHRAE/IES Standard 90.1-1989, but not in the 90.1 Code. For instance, the air leakage requirements are basic requirements and apply, even if the project uses the ECB method. The basic requirements still apply with the ECB method for several reasons:

- Many basic requirements cannot be accurately modeled (such as subdivision of feeders)
- Many requirements are inherently cost effective (such as energy-efficient motors)
- Some basic requirements are calculation methodologies that establish a fair basis for comparing component performance (such as U-value calculations)
- Some basic requirements are not intended for trade-offs (such exterior lighting)

OVERVIEW OF PROCEDURE

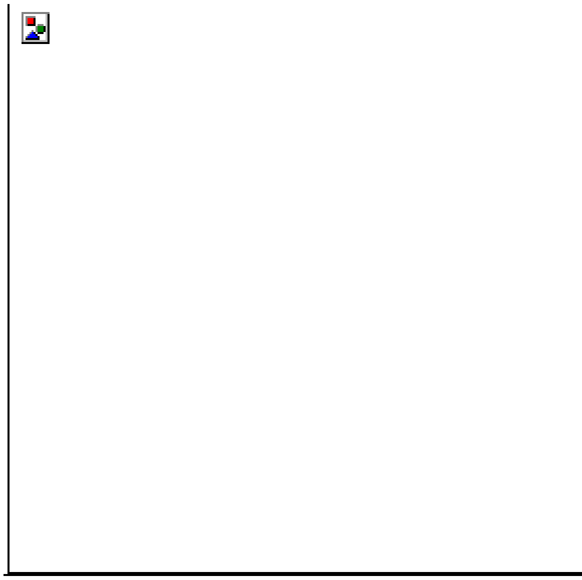
The general procedure is to show that the annual energy cost for your building is less than the annual energy cost of a budget building that meets either the prescriptive or system performance requirements. You have to estimate the annual energy costs for two buildings: the one you want to build and the budget building. (The budget building is defined as either a prototype building or a reference building.) Since the comparison is made on the basis of annual energy costs, designs that have lower demand charges or use energy when rates are lower are favored.

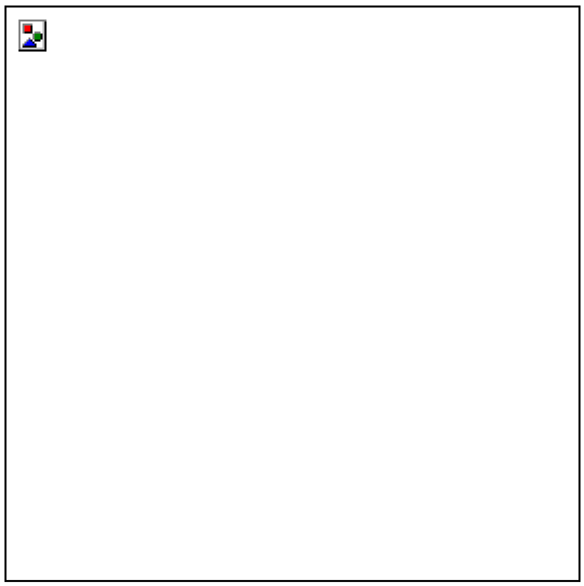
Generally, you use a prototype building for comparison when your building is designed for one of the following occupancies: assembly, health/institutional, hotel/motel, light manufacturing, multifamily high-rise, office (business), restaurant, retail (mercantile), school (educational), and warehouse (storage). If your design is a multi-use building made up of more than one of these occupancies, zone the prototype building with a combination of occupancies to best match your design. It is especially important that the assigned perimeter and interior spaces among the prototype classifications be similar to your design. The prototype building has the same occupancy type, gross floor area, conditioned floor area, and number of floors

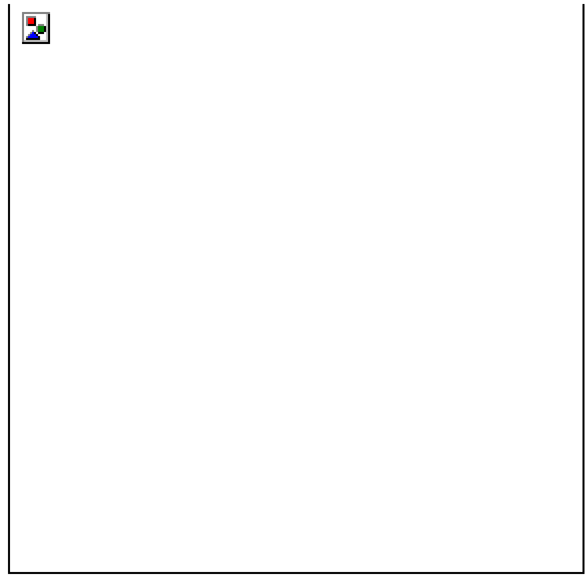


as your design, but is rectangular in shape with an aspect ratio of 2.5 to 1. The long facades of the building shall face east and west.

You compare your design to a *reference building* when the prototype cannot accurately represent your design. Examples of projects that would use a reference building include: sports arenas; mixed use projects with complex geometries such as large convention hotels or retail malls; assembly buildings with unique architecture or conditioning requirements such as symphony halls or museums; and transportation centers such as airports, bus stations, and train terminals. The reference building should have exactly the same form (footprint and height), orientation, and interior zoning as your design. However, it must meet all of the applicable prescriptive or system performance design criteria.







CHOOSING THE SIMULATION TOOL

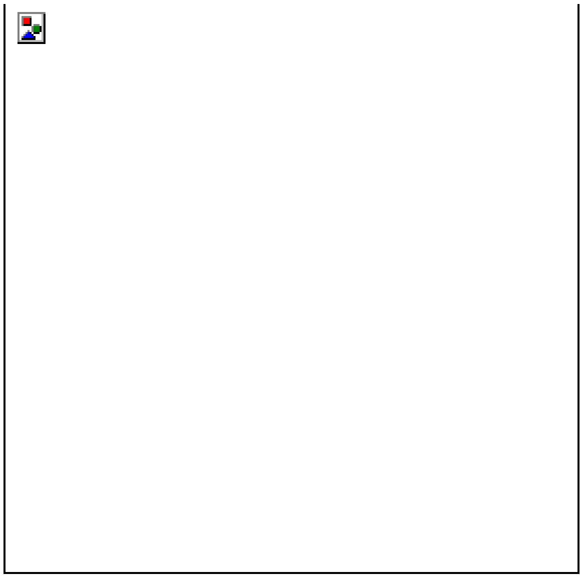
ASHRAE/IES Standard 90.1-1989 recommends that you use an hour-by-hour, full-year (8,760 hour), multizone program to simulate the performance of both the proposed and budget buildings. You can use other types of simulation tools that approximate the dynamics of the hourly energy programs, and that can be shown to produce equivalent results for the type of building and HVAC systems under consideration. However, the simulation must be capable of converting calculated energy demand and consumption into utility costs using the actual utility rate schedules (rather than average cost of electricity or gas).

Some examples of when an hour-by-hour, full-year type of program is required are:

- When the features intended to reduce energy consumption require time-of-day interactions between weather, loads, and operating criteria. Examples include: night ventilation and/or building thermal storage; chilled water or ice storage; heat recovery; daylighting; and water economizer cooling.
- When the appropriate utility rates are time-of-day sensitive, and the proposed design uses time-of-day load shifting between different types of mechanical plant components.

Another distinguishing feature among simulation programs is their sophistication in modeling HVAC systems and plant equipment. There are basically three levels of complexity employed: constant efficiency models; models with simple part-load efficiency adjustment; and models with complex part-load efficiency adjustment. Programs in the first category simply calculate hourly equipment input power requirements at part load by applying the full-load efficiency at any given hour. These programs should be avoided for all but constant load applications. Programs with simple part-load efficiency adjustments use a profile of percent-rated input power versus percent-rated load. At each hour, these programs calculate input power to each piece of equipment. These programs are far more accurate than the constant efficiency models, but still lack accurate compensation for environmental variables.

The most sophisticated programs incorporate a number of profiles for each and every piece of equipment. For variable flow fans, this might be as simple as a single profile of percent-rated input power versus percent-rated airflow. For more complex equipment, such as a cooling tower, the program considers such variables as the wet-bulb temperature, the approach (difference between the condenser water supply temperature and the wet-bulb temperature) and the range (difference between the condenser water entering and leaving temperatures). Each of these variables is used to adjust both the hourly capacity of the tower and the hourly operation (one fan, two



fans, no fans). For all but the simplest systems, programs of this category must be used to obtain accurate results.

In evaluating simulation tools, you should get one that permits you to incorporate your own equipment profiles. This is particularly helpful in evaluating relatively new equipment, such as direct-fired chillers and screw compressors.

A comprehensive listing of available energy analysis programs can be found in Larry Degelman and Guillermo Andrade, *A Bibliography of Available Computer Programs in the Area of Heating, Ventilation, Air Conditioning and Refrigeration*, ASHRAE, 1986. The entries contain a brief description of the program's capabilities. In some cases, these descriptions are sufficient to permit you to decide whether the capability of the program meets the requirements of the planned application. Questions regarding the program's ability to model the building on an hour-by-hour, full-year basis should be addressed to the program's author or distributor.

CLIMATE DATA

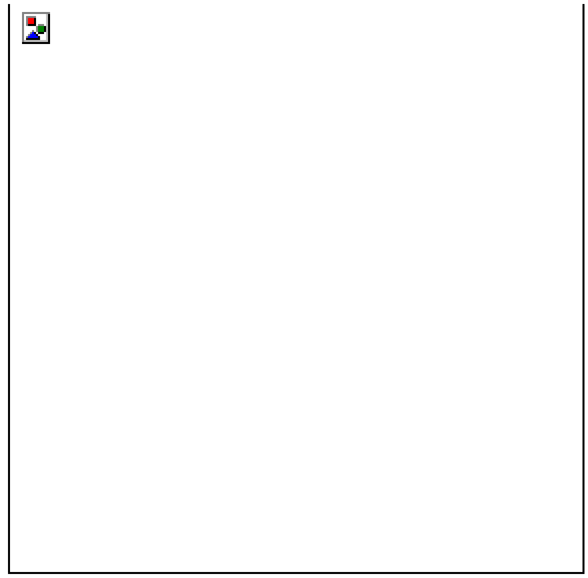
The weather data used with the simulation program must be appropriate for the site and complexity of the design's energy conserving features. Hourly weather data for use with the hour-by-hour, full-year programs should be reasonably representative of the building site, containing the peaks and valleys of the weather parameters that are typical of the area.

The simulation tool should take into account the following weather variables: dry-bulb temperature, wet-bulb temperature (or other indication of water content such as relative humidity), wind speed, wind direction, insolation (solar radiation), percent diffuse radiation, and cloudiness index. The data should be hourly in order to simulate dynamic site conditions. Simulations using averaged data can give erroneous results.

Similarly, HVAC equipment that is very sensitive to temperature extremes may not reveal inadequate performance capability if the extremes of typically high and low temperature have been smoothed out. For instance, a marginally sized cool storage system may appear to have adequate capacity when modeled with averaged weather data, while in actual practice a number of days may have above-average conditions for which the tank would be undersized.

Hourly weather data files are available from a number of sources, including:

(1) ASHRAE developed Weather Year for Energy Calculations (WYEC) files for 51 North American locations. These are considered to be the default hourly weather data if other, more suitable, data are not available. More recent WYEC2 data has 77 North American locations.

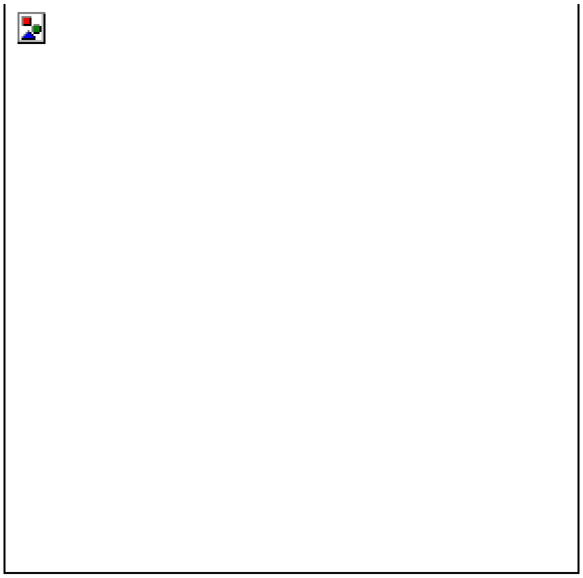


(2) The National Climatic Data Center (NCDC) in Asheville, North Carolina, can supply hourly weather data for hundreds of locations worldwide. The data can be for a specific calendar year or a composite year made up of typical months. One such composite is a Typical Meteorological Year (TMY) file. TMY files are compiled from statistical sampling of hourly data over a period of many years (23 years for most locations). NCDC can supply TMY files for 234 locations in the United States and her territories.

(3) Test Reference Year (TRY) weather files were assembled in a joint project by NCDC, the National Bureau of Standards (NBS), the National Oceanic Atmospheric Administration (NOAA), the Federal Energy Administration, and ASHRAE. Unlike WYEC and TMY files, TRY files contain data for only a single year. The reference years are selected from 25- to 30-years of data through a rigorous elimination of years which contain weather extremes. These files are less typical than WYEC or TMY files; they are not recommended unless other data sources are not available.

(4) Environment Canada can provide hourly data for almost all Canadian cities for specific calendar years.

Non-hourly weather data (bin data) are available from several sources and can be generated from the hourly data files described above. Bin data consists of the average number of hours that the ambient temperature in a given city will fall within specified 5-degree ranges (bins). One of the more common sources of that type of data is the Tri-Service Manual produced by the U.S. military services (AFM88-29, TM5-785 or NAVFAC P-89). Tri-services bin data is available for airports and military bases across the country and around the world. Summer and winter design conditions are identified (dry-bulb, wet-bulb, wind direction, and wind speed). Dry-bulb temperature bins are presented that are divided by both temperature and temporal ranges (the number of hours in a year that the temperature is between 80°F to 84°F between midnight to 8:00 a.m.). For each bin, a coincident wet-bulb temperature is given.

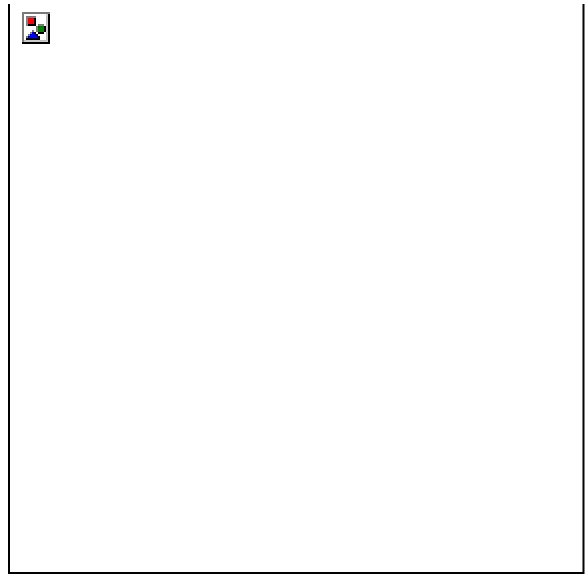


Defining the Budget Building

This section describes the methods and assumptions to be used in calculating the annual design energy cost (DECOS) of the proposed building, and the annual energy cost budget (ECB) of the budget building. It also describes the features of the proposed and budget buildings. The information is organized in three columns: the topic; the modeling rules for the proposed design; and the modeling rules for the budget building. The modeling rules are also grouped into four categories: building envelope; lighting and internal gains; HVAC systems and equipment; and service water heating.

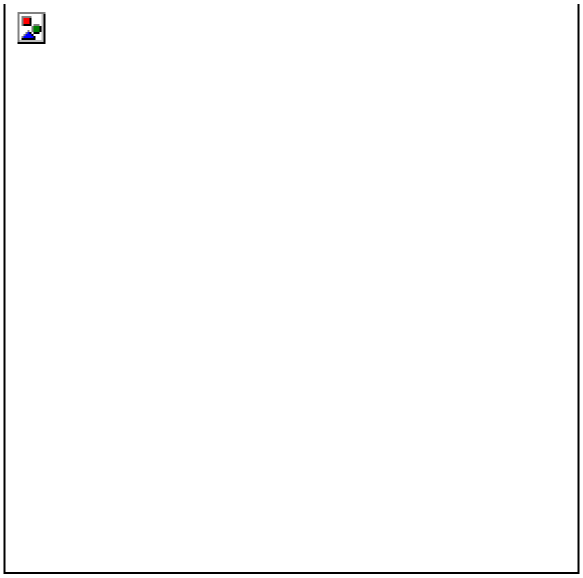
It must be emphasized that the design and operational characteristics of the budget building described below are *not intended to imply* typical or recommended values for any of the building types. They are merely a reference set of values to be used in setting a reasonable, repeatable energy budget that constitutes a constraint on the energy usage of a proposed design when calculated under similar sets of conditions.

Two types of input data are specified in Section 13 of ASHRAE/IES Standard 90.1-1989 for use in simulating the performance of the proposed and budget buildings: *Prescribed* values are to be used without variation. *Default* values are to be used unless more appropriate values for the specific building, system, or equipment are available.



Building Envelope

	Proposed Design	Budget Building
Building Shape	Model the proposed building as it is designed. The building must generally have at least five thermal zones per floor.	The *reference* building is identical to the proposed design, except building components must comply with the prescriptive or systems performance requirements. The *prototype* building has the same floor area and number of stories as the proposed design, but the building is rectangular in shape with an aspect ratio of 2.5 to 1.0 and the long dimension extending in an east west direction.
Roof Constructions	Model the roof constructions as they appear on the plans and specifications, including consideration of thermal mass if applicable.	Model a lightweight roof construction meeting the prescriptive criteria.
Wall Constructions	Model the wall constructions as they appear on the plans and specifications, including thermal mass.	Model a lightweight wall construction meeting the prescriptive criteria.
Floor Constructions	Model the floor constructions as they appear on the plans and specifications, including thermal mass.	Model a lightweight floor construction meeting the prescriptive criteria.
Infiltration	Use default infiltration of 0.38 cfm/ft^2 of gross exterior wall area unless detailed calculations are made (no infiltration while HVAC system is operating)	Fix infiltration at 0.38 cfm/ft^2 of gross exterior wall area (no infiltration while HVAC system is operating)
Envelope and Ground Absorptivities	Assume 70% absorptivity for all exterior walls and roof elements. Assume 20% absorptivity for the ground.	Same as proposed design.
Fenestration (windows)	Model fenestration as it is shown on the plans and specifications, including orientation, overhangs, sidefins, U-values, shading coefficients, and visible light transmissions.	Model a shading coefficient of 0.65. Assume the fenestration U-value is at the upper limit of the range in the first column of the ACP tables. Fenestration area shall be that allowed for the above U-value and shading coefficient values and with no overhang.
Overhangs and Sidefins	Model overhangs and sidefins as shown on the plans.	No overhangs or sidefins.
Skylights	Model the skylights as they appear on the plans and specifications. Daylighting benefits can be modelled with the simulation tool or the standard daylighting credits can be assumed.	No skylights. Model skylight areas in the proposed design as lightweight roofs meeting the prescriptive criteria.
Interior Shading Devices	Model draperies or blinds if they are shown on the plans and/or specifications, otherwise do not model draperies or blinds. If modelled, draperies are assumed to permanently cover half the window area.	Do not model draperies or blinds.
Exterior Shading Devices	If the proposed design has specially designed exterior shading devices such as moveable sunscreens, louvers or canopies, model these in the proposed design, including special controls that are part of the design.	No exterior shading devices.
Shading from the Site	Model shading from buildings, trees, or terrain that are expected to remain for the life of the building.	Model the same shading conditions as the proposed building.



Lighting and Internal Gains

	Proposed Design	Budget Building
Lighting Power	Use the connected lighting power from the plans and specifications. If qualifying automatic controls are installed, use the adjusted lighting power (see below). For speculative buildings, use the same lighting power as the budget building.	Determine the lighting power using either the prescriptive or systems performance method. If the prescriptive method is used, assume that the lighting power is uniformly distributed throughout the zones. If the systems performance method is used, distribute the lighting power by zone according to the system performance allocations.
Lighting Operation Schedules	Use the lighting schedule for the proposed building if known, or use a schedule from Table 13-5 of ASHRAE Standard 90.1 for the occupancy type that best matches your design.	Same as the proposed design.
Daylighting Controls	Model daylighting controls if they are included in the plans and specifications and if the analysis tool can model daylighting. If the proposed design has daylighting controls, but the analysis tool cannot model daylighting, approximate the daylighting benefits using the lighting power control credits (see Table 6-3 of ASHRAE Standard 90.1)	No daylighting controls.
Other Automatic Lighting Controls	Adjust the connected lighting power by the control credits in Table 6-3 of ASHRAE Standard 90.1, when qualifying automatic controls are part of the proposed design.	No automatic controls.
Occupancy Load	Use the occupant load for the proposed design if it is known. Otherwise select an occupant load from Table 13-1 of ASHRAE Standard 90.1.	Same as proposed design.
Occupancy Schedules	Use the occupancy schedule for the proposed building if known, or use a schedule from Table 13-5 of ASHRAE Standard 90.1 for the occupancy type that best matches your design.	Same as the proposed design.
Receptacle Load	Use the receptacle load for the proposed design if it is known. Otherwise select receptacle load from Table 13-2 of ASHRAE Standard 90.1.	Same as proposed design.
Receptacle Schedules	Use the receptacle schedules for the proposed building, if known, or use a schedule from Table 13-5 of ASHRAE Standard 90.1 for the occupancy type that best matches your design.	Same as the proposed design.

HVAC Systems and Equipment

	Proposed Design	Budget Building
Air-Conditioned Spaces	Model the HVAC system as shown on the plans and specifications.	For the *prototype* building, select a mechanical system from Table 13-3 of ASHRAE Standard 90.1. For the *reference* building, model the same system type as in the proposed building, but one that exactly complies with Sections 9 and 10 of ASHRAE Standard 90.1.
Nonresidential Zones	Create thermal zones for the proposed design that correspond to the zones served by the HVAC system. Similar zones may be grouped for modeling purposes. There should generally be at least five zones for each floor: an interior zone and four perimeter zones. The interior zone can be eliminated, however, for buildings that are less than 30 ft wide. Also light manufacturing, assembly, and warehouse spaces may be modeled as a single zone if so controlled.	The *prototype* building shall have five zones per floor. The *reference* building shall have the same zoning as the proposed design.
Residential Zones	At least one zone per dwelling unit, but multiple zones may be created for dwelling units that have suitable controls.	One zone per dwelling unit.
HVAC Operation	Use the operation schedule for the proposed building or select a schedule from Table 13-5 of ASHRAE Standard 90.1 based on the occupancy that is most similar.	Same as the proposed design
Thermostat Setpoint	Choose a schedule from Table 13-2 ASHRAE Standard 90.1.	Same as the proposed design
HVAC Equipment and Component Performance	Model the equipment and components shown on the plans and specifications.	For the *prototype* building, equipment and components should meet the exact requirements of Section 10 of ASHRAE Standard 90.1. For the *reference* building, upgrade or downgrade the equipment to meet the exact requirements of Section 10 of ASHRAE Standard 90.1.
Process Equipment and Loads	Model known process loads to allow equipment that might serve combined conditioning and process loads to be properly sized and the energy costs calculated at the proper utility rate steps.	Include the same process loads as the proposed building.
Equipment Sizing	Model all air flows, water flows, and equipment capacities as specified on the plans. However, if process loads are not modeled, then equipment capacity may be reduced accordingly. It is not acceptable to allow the analysis tool to automatically size components or equipment.	Size equipment to meet the requirements of Section 9.4(a) OF ASHRAE Standard 90.1 without using any of the exceptions to 9.4(a). If process loads are included in the proposed design, the equipment shall be sized according to 9.4(a) to meet both the process and space conditioning loads.
Outside Air Ventilation	Model the outside air ventilation as designed.	Model outside air ventilation either the same as the proposed design or as in ASHRAE Standard 62-1989, whichever is greater. Completely shut off outside air during setback, warm-up, and unoccupied periods.

Redundant Equipment	Ignore equipment for backup or emergency services if it is controlled such that it will not be operated during normal building operation.	Same as the proposed design.
Dehumidification	Model the system as designed.	If subcooling of the supply air is required for dehumidification, then provide reheat for the budget building from recovered waste heat (such as condenser heat recovery).

Service Water Heating

	Proposed Design	Budget Building
Service Water Heater	Model the water heating system as designed and shown on the plans and specifications.	Model an electric heat pump if the proposed building uses electricity for water heating. Otherwise, model a gas- or oil-fired water heater meeting the minimum efficiency requirements of Section 11 of ASHRAE Standard 90.1.
Hot Water Consumption	Use anticipated consumption for the proposed building or take consumption values from Table 13-1 of ASHRAE Standard 90.1 for the appropriate occupancy type. Table 13-3 must be used for residential occupancies.	Same as the proposed design.
Hot Water Consumption Schedule	Use anticipated hot water consumption schedule or use a schedule from Table 13-5 of ASHRAE Standard 90.1 for the most similar occupancy.	Same as the proposed design.